Future Russian magnetospheric & heliospheric missions

L.M. Zelenyi, A.A. Petrukovich, G.N.Zastenker, M.M.Mogilevsky, A.A.Skalsky

Space Research Institute, Russia

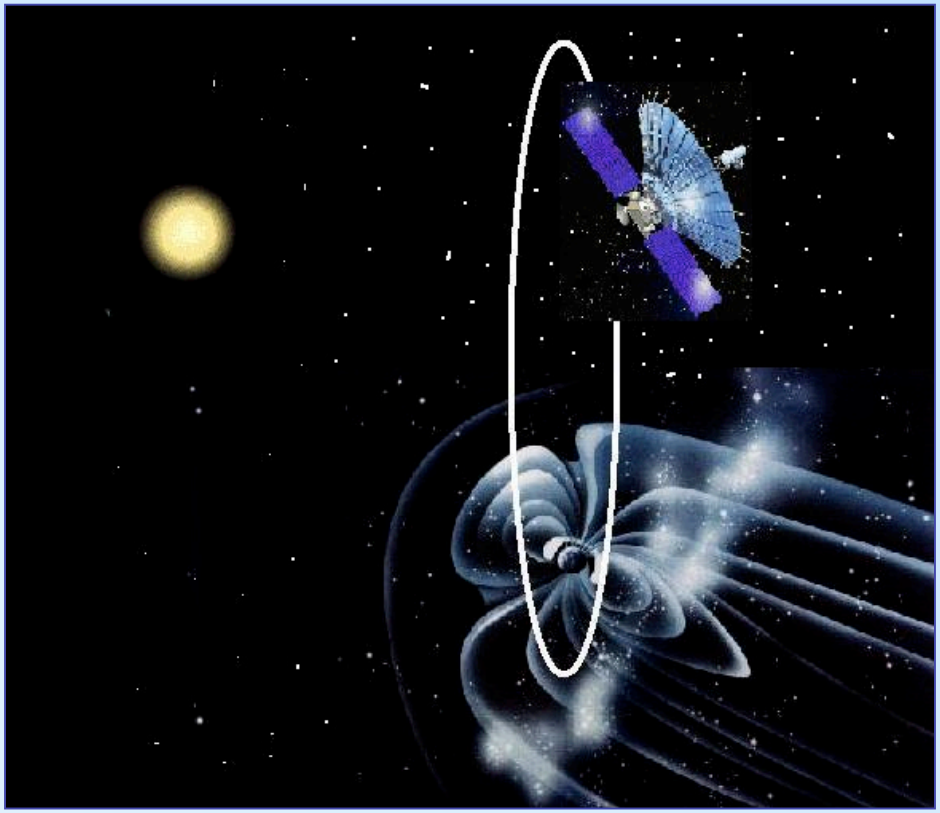
V.D.Kuznetsov

IZMIRAN, Russia

Yu. Kotov

MEPhI, Russia

Solar-terrestrial payload onboard SPECTR-R



SPECTR-R is an international space VLBI project of Russian Space Agency.

A 10-meter radio telescope will be launched in late **2007** to an orbit with
apogee 350 000 km,
perigee 5 000 km
inclination 54°.

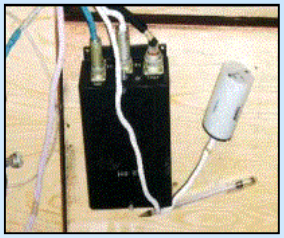
PLASMA-F is solar-terrestiral payload of opportunity onboard SPECTR-R.

Targets:

- Fine-scale solar wind, IMF, SCL structures
- Solar wind, IMF, SCL monitoring

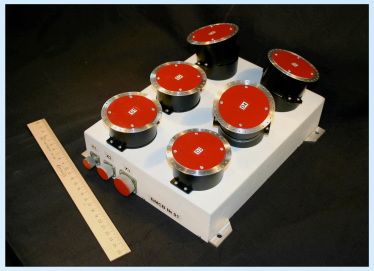
With participation of Slovakia, Czech Rep., Greece, Ukraine, China

PLASMA-F instruments



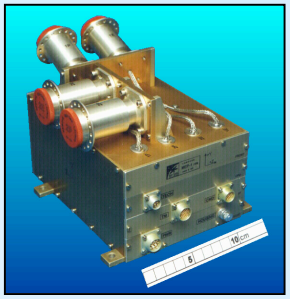
Magnetic field instrument MMFF

2 DC magnetometers
2 AC magnetic sensors (10 Hz – 100 kHz)
PI: A. Skalsky, IKI, w/part LSC



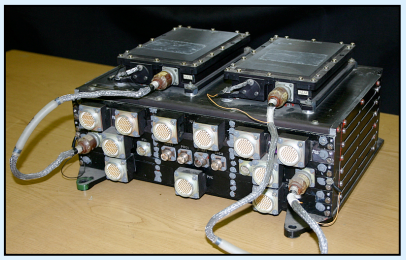
Fast solar wind monitor BMSW

6 Faraday cups with possibility of instantaneous
solar wind velocity vector and density determination
PI: G. Zastenker, IKI, w/part ChU, CSS



Energetic particle instrument MEP2

geometric factor ~ 1
electrons 15-350 keV
ions 15- 3200 keV
PI: K. Kudela, IEP, w/part DUTH/SSL, IKI



Data management system SSNI-2

200 GB onboard memory
possibility of intelligent data handling and compression
PI: L. Chesalin, IKI

PLASMA-F features

- ☹ Synchronized 32 Hz measurements of magnetic field, solar wind ion density, velocity vector, temperature, energetic ions and electrons.
- ☹ Multi-point solar wind observations with other projects in the frame of ILWS.
- ☎ 1 GByte of data per week
- ☎ Tests of intelligent onboard data handling

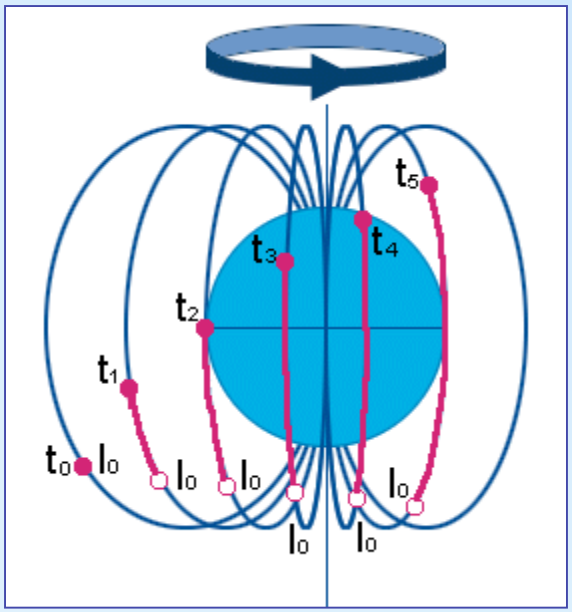
Fast-track experiment: decision taken & funding started end of 2004
launch end of 2007

Project Scientist: G.N.Zastenker gzastenk@iki.rssi.ru

RESONANCE

Investigation of wave-particle interactions and plasma dynamics in the inner magnetosphere

Space Research Institute, Moscow
Institute of Applied Physics, N.Novgorod
European participation



Magnetosynhronous orbit

Orbit:
Apogee: ~30 000 km,
Perigee: ~ 1 800 km,
Inclination: + and - 63.4^{o} (two S/C)

Co-rotation magnetic tube: up to 3 hours

Launch: 2012

http://resonance.romance.iki.rssi.ru

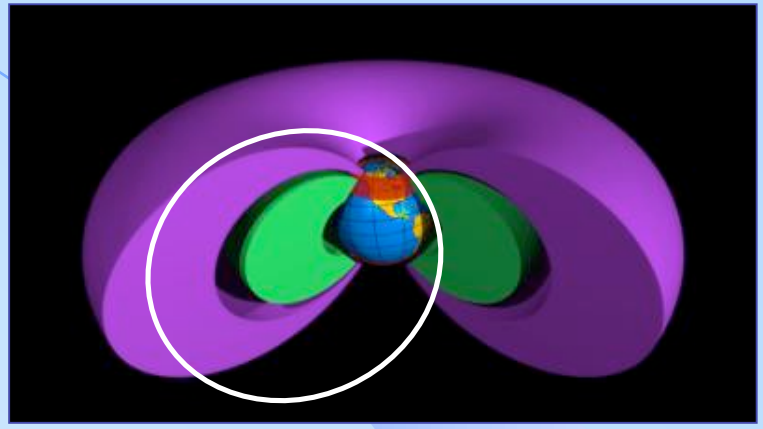
RESONANCE

Magnetospheric science and space weather-related investigations:

Ring current and outer radiation belt dynamics

Plasmasphere & plasmapause dynamics

Sub-auroral zone, auroral zone, polar cap

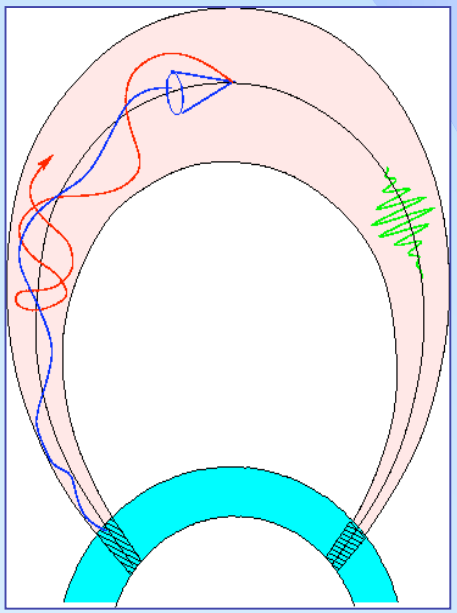


Special task:
magnetospheric cyclotron maser observations and active experiments

Excitation of waves

Modification of precipitation

Modification of reflection index at the footprints



RESONANCE

Launch 2012: will operate at the same time with

- **Radiation Belt Storm Probes by NASA LWS**
- **ERG**
- **ORBITALS**

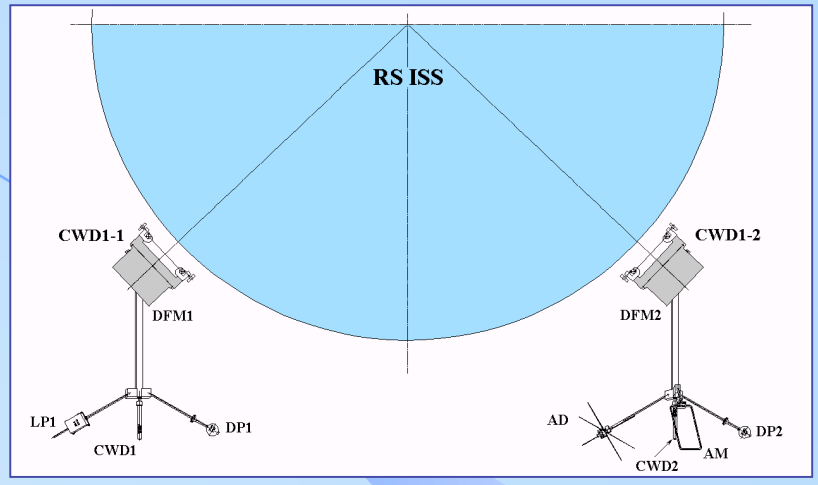
ILWS inner magnetosphere constellation in 2012 ?

International Space Station

electromagnetic environment experiment "Obstanovka"

Multipoint multi-component wave and field experiment.

Deployment – 2007, by IKI



Electra-L: geostationary meteosat, in eastern longitude sector.

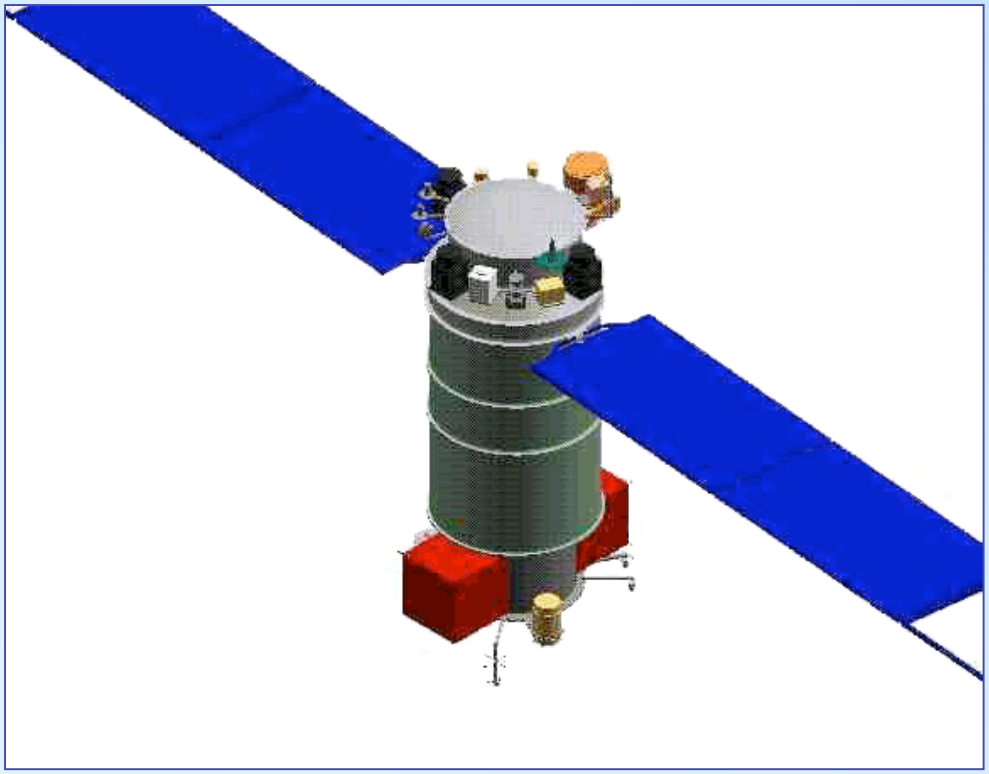
MeV-range particles
KeV-range particles
X-ray photometer
Magnetometer

to be launched in 2007, Institute of Applied Geophysics, Meteoservice

CORONAS-PHOTON

Solar imaging and spectroscopy from EUV to 2000 MeV

To be launched in 2007

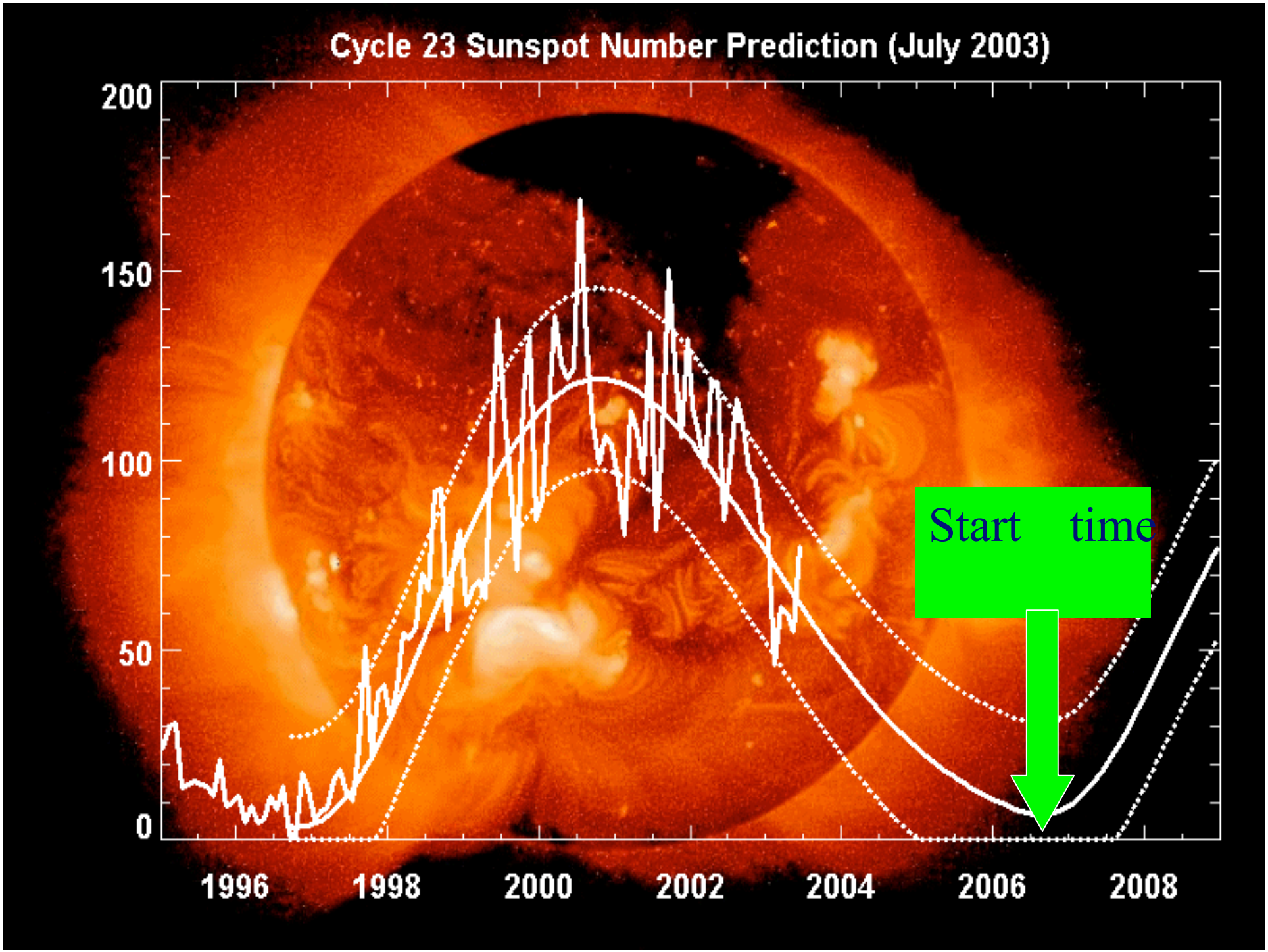


Moscow Engineering
Physics Institute

Yu. Kotov

http://iaf.mephi.ru

RUSSIA
UKRAINE
INDIA
POLAND


Cycle 23 Sunspot Number Prediction (July 2003)
200
150
100
50
0
1996
1998
2000
2002
2004
2006
2008
Start time

Project "CORONAS-PHOTON"

CORONAS (**C**omplex **OR**bital **O**bservations **N**ear-Earth of **A**ctivity of the **S**un) – Russian program for study of the Sun and solar-terrestrial connections physics by series of spacecrafts, which provides launching of three solar-oriented satellites onto the near-Earth orbit.

"CORONAS-PHOTON" is the third satellite in this series. Two previous missions of the project are "CORONAS-I" (launched on March 2, 1994) and "CORONAS-F" (launched on July 31, 2001).

Launching date of "CORONAS-PHOTON" spacecraft is 2006.

MEPhI – Moscow Engineering Physics Institute (State University) is the main organization responsible for the scientific payload complex of the "CORONAS-PHOTON" mission.

NIIEM – Research Institute for Electromechanics (Moscow region, Istra) is the main organization responsible for the spacecraft "CORONAS-PHOTON".

Principal Investigator of the project – Director of Astrophysics Institute at MEPhI **Dr. Yuri D. Kotov**

Technical director and chief designer of the spacecraft – Deputy Chief Designer of NIIEM **Dr. Rashid S. Salikhov**

Main goal of the project:

The investigation of energy accumulation and its transformation into energy of accelerated particles processes during solar flares; the study of the acceleration mechanisms, propagation and interaction of fast particles in the solar atmosphere; the study of the solar activity correlation with physical-chemical processes in the Earth upper atmosphere.

Objectives of the mission:

Physics of the Sun

- Determination of distribution functions of accelerated electrons, protons and nuclei and their dynamics with a high time resolution;
- Research of difference in acceleration dynamics of electrons and protons (nuclei);
- Research of distribution function variations for high energy particles (up to a few GeV);
- Research of interacting particle angular anisotropy by statistical analysis of radiation spectra and linear polarization parameters of hard X-rays;
- Study of directional effects in the region of high energy gamma radiation;
- Determination of mechanisms and requirements of electrons and protons acceleration in different flare phases, and parameters of propagation region of accelerated particles;
- Determination of elemental abundance in the region of gamma-ray production by gamma spectroscopy and capture of low energy neutrons in the solar atmosphere;
- Determination of radiation generation altitudes by observation of deuteron line weakening from limb flares;
- Determination of energy spectra view of accelerated protons and nuclei and dynamics of these spectra according to nuclear gamma-line ratio;
- Study of light elements generation (D, ^{3}He, Li, Be) during flares;

Solar-terrestrial connections physics

- Research of chemical and isotopic compositions of nuclei accelerated in flare on the Earth orbit, and also energy and temporal parameters of flare electrons and protons;
- Monitoring of the Earth upper atmosphere by absorption of extreme ultraviolet of the quiet Sun;

Astrophysics

- Study of hard X-ray and gamma radiation from gamma-ray bursts;
- Study of X-ray radiation from the bright local sources along Ecliptic plane.

MAIN CHARACTERISTICS OF THE SPACECRAFT

Spacecraft weight, kg ……... 1900
Scientific payload weight, kg .....…….....…… 540
Orbit:
· type ……..…. circular
· height, km ……..…… 500
· inclination, deg ……..…….. 82.5
Accuracy of the spacecraft longitudinal axis orientation to the Sun, arc min ….better than 5
Determination accuracy of the spacecraft longitudinal axis orientation on the Sun, arc min .. 3
Angular velocity stabilization of the spacecraft, deg/s ……..... less than 0.005
Accuracy of the satellite position measurement:
•along the orbit, m …….. ±1000
•by height and in transverse directions, m …… ±500
Volume of scientific information stored per day, Gbit ……..…… 8.2
Information transmitted during one communication session, Mbit …..…...……..…. 2048
Nominal mission lifetime, years ……..…….. at least 3

SCIENTIFIC PAYLOAD COMPLEX

"PHOTON"

Instrument	Parameters registered radiation	Developing organization
Electromagnetic radiation and neutrons		
High energy spectrometer **"NATALYA-2M"**	• Gamma-ray spectroscopy 0.3– 2000 MeV; • solar neutrons 2θ 300 MeV	Moscow Engineering Physics Institute (MEPhI), Russia
Low energy gamma-ray telescope **RT-2**	• Hard X-ray spectroscopy 10– 150 keV in phoswich mode; • spectrometric mode 0.10 – 2 MeV	TATA Institute of Fundamental Research (TIFR), Mumbai (Bombay), India
Hard X-ray polarimeter-spectrometer **"PENGUIN-M"**	• Hard X-ray polarization 20 – 150 keV; • soft X-ray monitoring 2 – 10 keV; • X-ray & gamma-ray spectroscopy 0.015 – 5 MeV	Ioffe Physical-Technical Institute, St-Petersburg, Russia; MEPhI, Russia
X-ray and gamma-ray spectrometer **"KONUS-RF"**	Solar flares and gamma-ray bursts hard X-ray & gamma-ray spectroscopy in the energy range of 10 keV– 12 MeV with high time resolution	Ioffe Physical-Technical Institute, St-Petersburg, Russia

SCIENTIFIC PAYLOAD COMPLEX

"PHOTON"

X-rays		
Fast X-ray monitor **BRM**	Hard X-ray monitoring 20– 600 keV in six channels with time resolution 2 – 3 ms	MEPhI, Russia
Multi-channel ultraviolet monitor **PHOKA**	• Full disk EUV radiation 1– 130 nm in six spectral windows • occultation measurements of UV absorption in Earth atmosphere 150 – 500 km	MEPhI, Russia; Astrophysical Institute of Potsdam (AIP), Germany; Fraungofer Institute (IpM), Freiburg, Germany
Solar telescope/imaging spectrometer **TESIS**	Sun full-disk image in spectral channels: • 134A: $\lambda/\Delta\lambda$ = 10, spatial res. ~ 1'' • 304A: $\lambda/\Delta\lambda$ = 10, spatial res. ~ 1'' Field of view: Disk 35', Corona (2÷5) R_{Sun} • 8.418÷ 8.423A: $\lambda/\Delta\lambda = 2x10^{-4}$/cell, spatial res. = 2'', Field of view: 45' (full disk)	Lebedev Physical Institute (LPI), Moscow, Russia

SCIENTIFIC PAYLOAD COMPLEX

"PHOTON"

Cosmic rays		
Charged particle analyzer **"ELECTRON-M-PESCA"**	Flux and energy spectra registration: • protons 1 – 20 MeV; • electrons 0.2 – 2 MeV; • nuclei ($Z < 26$) 2 – 50 MeV/nucleon	Scobeltsyn Institute of Nuclear Physics at Moscow State University, Russia; University de Alcala, Madrid, Spain
Satellite telescope of electrons and protons **STEP-F**	Flux and energy spectra registration: • protons 9.8 – 61.0 MeV; • electrons 0.4 – 14.3 MeV; • α- particles 37.0 – 246.0 MeV with particle direction measurement accuracy 8 – 10°	Kharkov National University, Ukraine

SCIENTIFIC PAYLOAD COMPLEX

"PHOTON"

Scientific supply systems		
Magnetometer **SM-8M**	Measurements of three components of constant magnetic field on satellite orbit in the range of –55 μT … +55 μT	FGU NPP "Geologorazvedka" St-Petersburg, Russia; MEPhI, Russia
Scientific data acquisition and registration system **SSRNI**	Scientific data reception from 24 digital array sources by parallel interface up to 125 Kbit/s; online stored memory si – not less than 4 Gbit; transmitting speed in radio k not less than 7.68 Mbit/s	Space Research Institute, Moscow, Russia
Control and communications block **BUS-FM**	Power supply and instrument control with 200 single commands and programmed command information	Space Research Institute, Moscow, Russia
X-band radio transmitter set 8.2 GHz	Scientific data transmission to the ground station in the frequency range of 8.2 GHz (X-band), output power 8 W; includes transmitters, feeders and antenna	Russian Institute of Space Device Engineering, Moscow, Russia

Phobos – SAMPLE RETURN

Sample return mission from Phobos **Launch 2009**

Plasma package onboard:

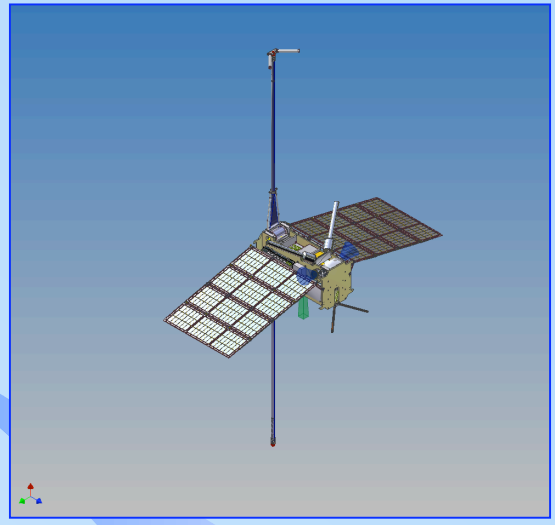
Magnetic field
Solar wind ions
Planetary ions

Multi point heliospheric measurements with STEREO, Messenger ?

Microsatellites

Kolibri, 2002 20.5 kg

TATIANA (MSU)-2005



Chibis, 2008 40 kg

- **IKI design and manufacturing**
- **Launch in LEO orbit from a space station or piggy-back**

Scientific tasks:

- Ionospheric monitoring: plasma and wave measurements
- CO2 and atmosphere composition
- Med-resolution surface imaging
- Educational programs

INTERHELIOPROBE

MAIN SCIENTIFIC GOALS

- to identify mechanisms of the coronal heating and solar wind
- to investigate the fine structure and dynamics of the solar atmosphere
- to determine the origin and study the global dynamics of the most powerful solar a ctivity phenomena (solar flares and CMEs) and their influence on the heliosphere and space weather
- to investigate generation and propagation of solar energetic particles
- to observe from high latitudes and to investigate the solar atmosphere and corona in the polar and equatorial regions
- to determine the mechanism of the solar dynamo and solar cycle

INTERHELIOPROBE: heliospheric mission with perihelion 30 Rs After 2012

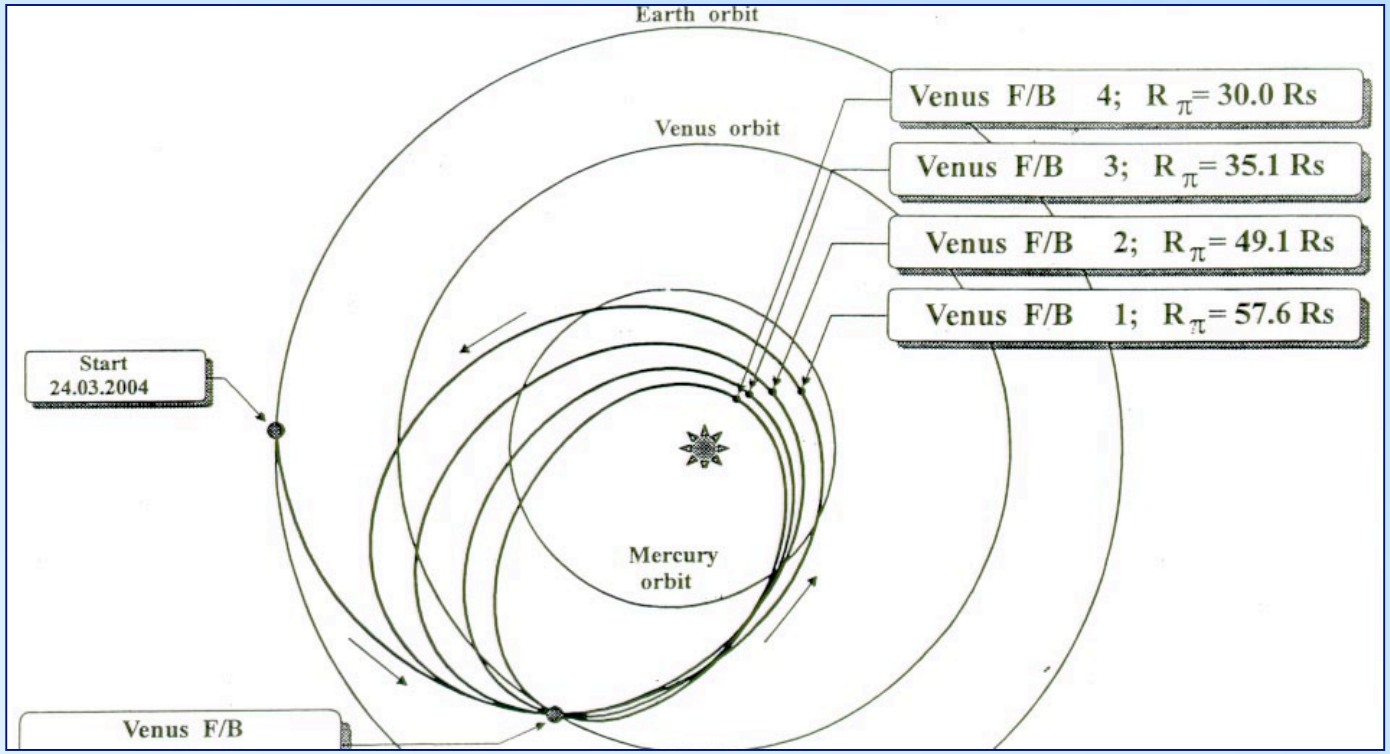
Solar Instrumentation
- Optical telescope
- Magnetograph
- X-ray imager-spectrometer
- Coronagraph

Heliospheric instrumentation
- Solar wind ion, electron analyzer
- Dust analyzer
- Magnetic, wave and radio instrument
- Energetic particle telescope
- Neutron detector

Payload 50-60 kg

Launch after 2011

Joint IZMIRAN & IKI project

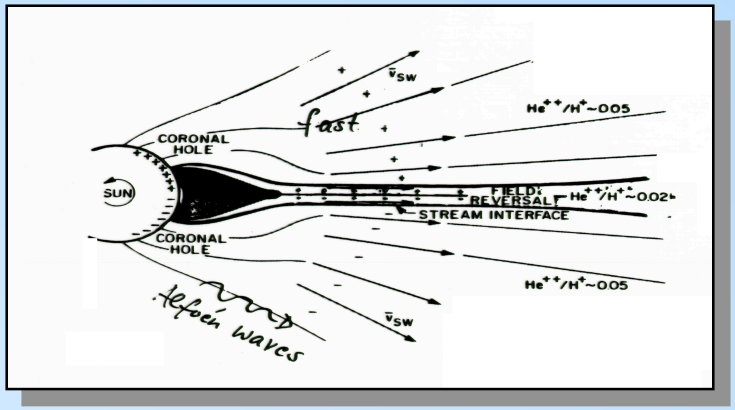


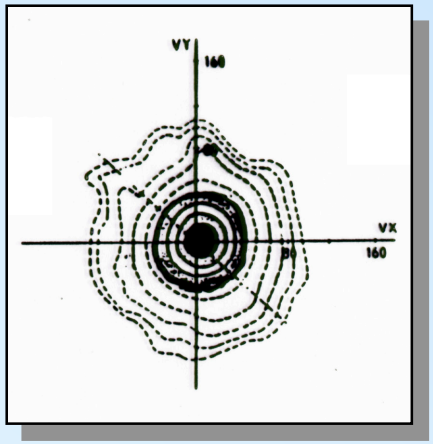
INTERHELIOPROBE

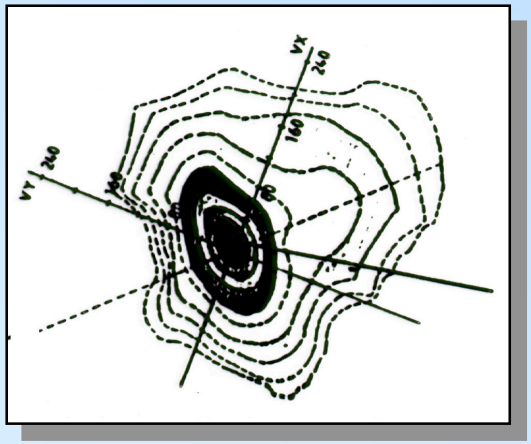
BALLISTIC SCENARIO OF THE MISSION

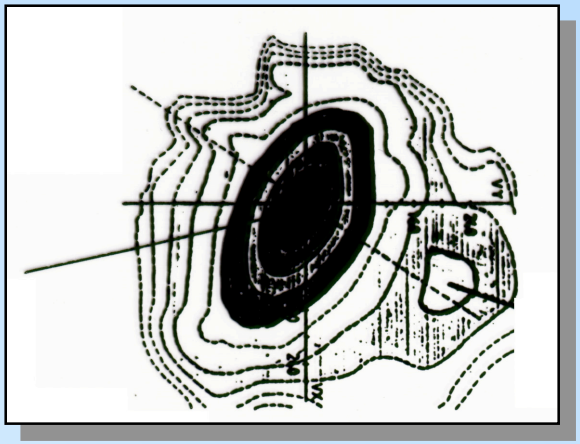
- multiple gravity-assisted manoeuvres near the planet Venus(VGM
-
-
-
-
-

In - situ measurements near the Sun









Distribution function. Remnants of coronal heating and related plasma processes.

Wave-particle interactions.

Waves and particles diagnostics.

Beams.

Temperature anisotropy.

Waves and turbulence generation.

Radio emission. Neutrons.

INTERHELIOPROBE

a novel orbital design allow

HIGH-RESOLUTION OBSERVATIONS OF THE SOLAR ATMOSPHERE

CO-ROTATION OBSERVATIONS AND MEASUREMENTS

IN-SITU MEASUREMENTS NEAR THE SUN

OUT-OF-ECLIPTIC OBSERVATIONS

STEREO OBSERVATIONS OF THE SUN

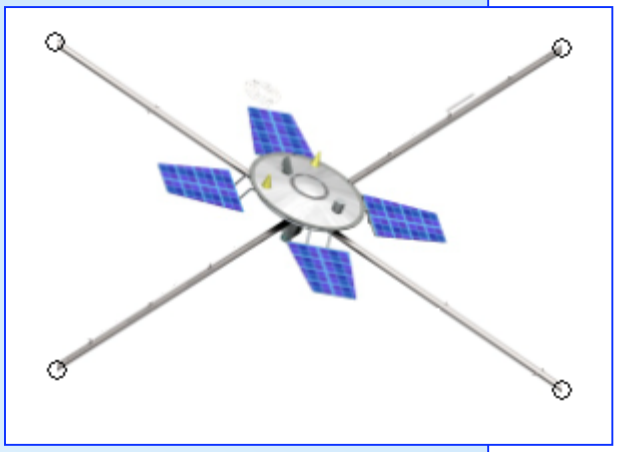
MULTIPLE PERIODS OF OBSERVATIONS OF INVISIBLE SIDE OF THE SUN

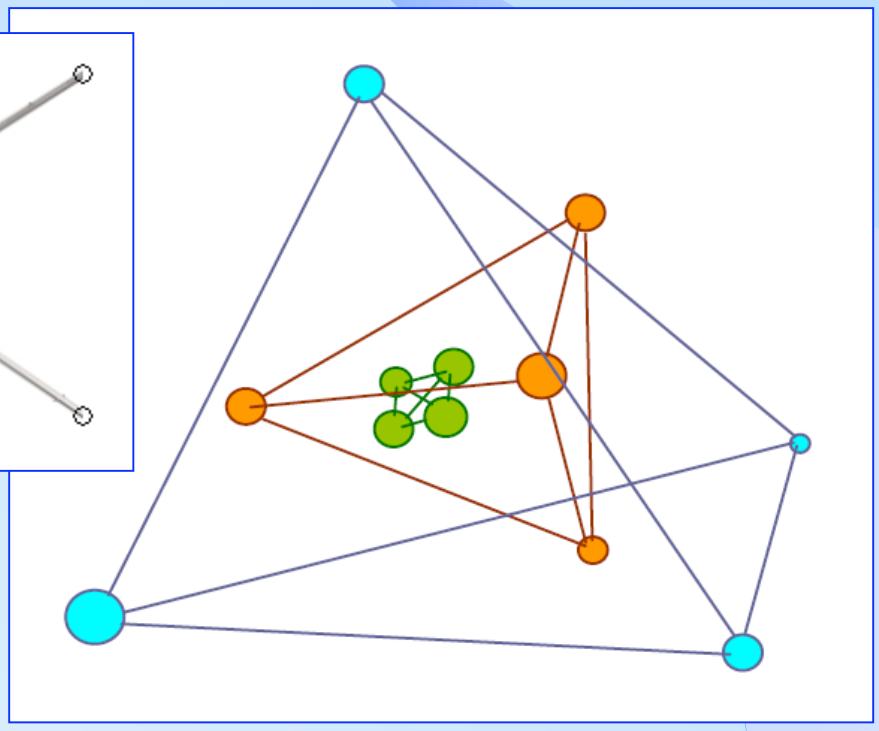
Mini-spacecraft for magnetospheric science_(”TRAVELLER””)

Currently under development, first launch of the platform in 2008

Possible collaboration with future MMS / X-scale projects

Sci payload weight ~ 40 kg





In a NUTSHELL: UPDATE

- SHORT term: **SPECTR-R/Plasma-F**
  CORONAS_PHOTON
  ISS, *CHIBIS*

- MID-term: **PHOBOS, RESONANCE**
  Geostationary (ELECTRA…..)

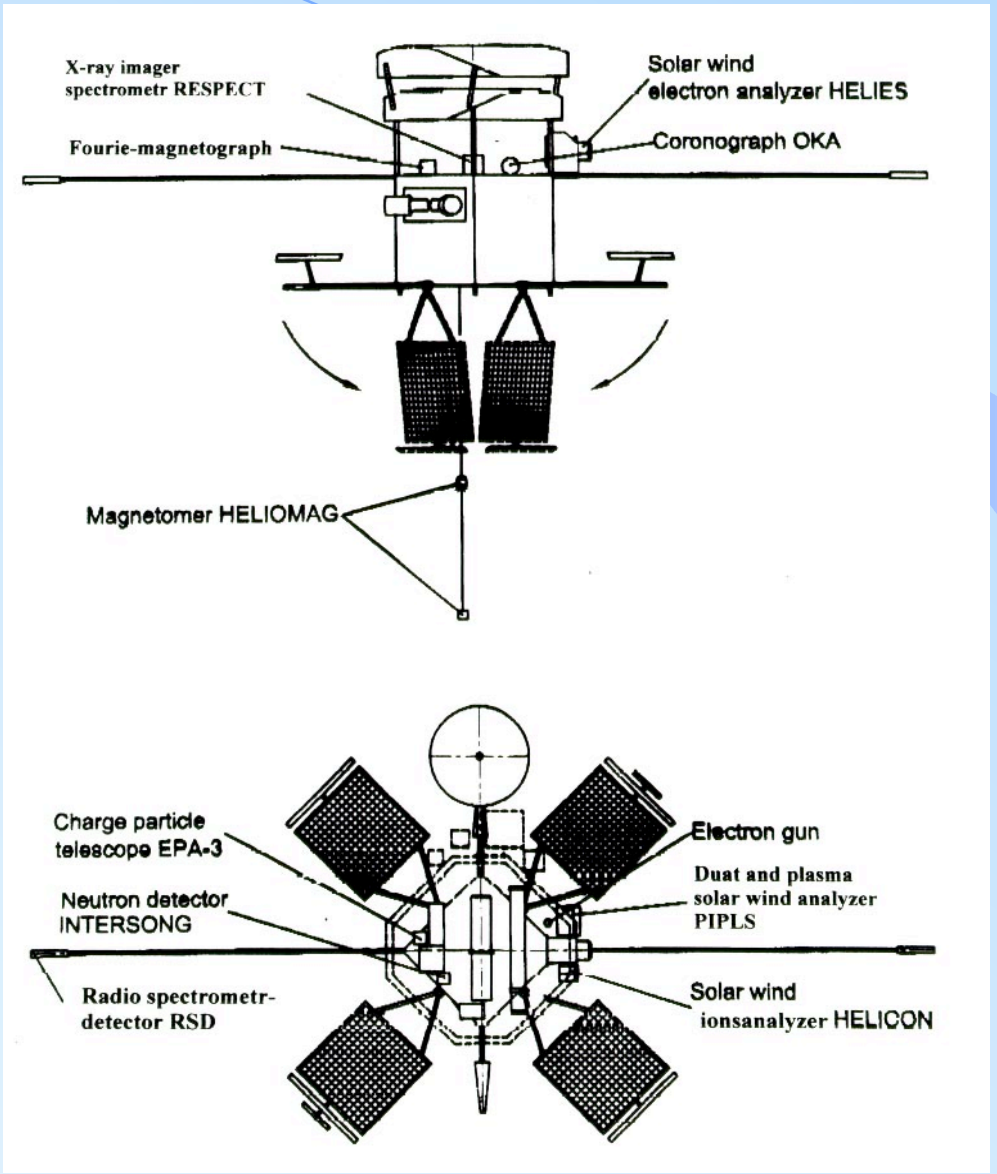
- LONG-term: **InterHelioProbe, Traveller,**

INTERHELIOPROBE

SPACECRAFT

- 3-axis stabilized
- Sun-pointing
- Pointing stability 3″/15 min
- Thermal shield
- Electric propulsion low thrust system (4 thrusters)
- Solar arrays (4 m^2)
- High-gain antenna (Ka-/X-band)
- Low-gain antenna (X-band)
- Launcher: Souyz-2

INTERHELIOPROBE SPACECRAFT



INTERHELIOPROBE

PAYLOAD

- Mass: 50-70 kg
- Power: 100 W
- Telemetry: 60 kb/s
- Two instrument packages
  Heliospheric instrumentation (in-situ measurements)
  Solar instrumentation (remote sensing observations)
- Instrumentation heritage
  APEX (launched 1991)
  CORONAS-I (1994)
  INTERBALL (1995)
  CORONAS-F (2001)

INTERHELIOPROBE

SOLAR INSTRUMENTATION

- OPTICAL TELESCOPE
- MAGNETOGRAPH
- X-RAY IMAGER-SPECTROMETER
- CORONAGRAPH

INTERHELIOPROBE

HELIOSPHERIC INSTRUMENTATION

- Solar Wind Ion Analyzer
- Solar Wind Electron Analyzer
- Solar Wind Plasma and Dust Analyzer
- Magnetic Wave Complex
- Magnetometer
- Energetic Particle Telescope
- Neutron Detector
- Radio Spectrometer Detector
- Electron Gun